Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE MEASUREMENT OF THE INTENSITY OF GRAVITY ON THE OCEAN AND ITS SIGNIFICANCE

BY

G. W. LITTLEHALES

Considering the degree of advancement that has long since been reached in the adaptation of instrumental means to the necessities of gravitational research on the land, it was remarkable that, up to the beginning of the Twentieth century, no beginning had been made in gathering observations to reveal a knowledge of the intensity of gravity over the oceanic areas. The unsteadiness of the observing platform and the consequent effect upon the inertia of masses, even under exceptional circumstances of calm at sea, are such as to preclude the application of methods depending upon the measurement of the time of flight of a plummet, or the oscillation of a pendulum, or, in any direct way, the changing relation, with change of locality, between a given mass and its weight.

Nearly thirty years ago attempts were made to determine the variation of the intensity of gravity, from place to place, by employing a syphon barometer whose short arm was closed, and contained a certain quantity of gas. At a given temperature this gas had a certain volume and exerted a certain pressure to contribute toward balancing the mercurial column; the greater the intensity of gravity, the greater would be the relative heaviness of the mercury and the shorter would be the barometric height corresponding to the pressure. The required exactness could not be attained either on the land or on the sea by this method because of the insuperable difficulties that arose in ascertaining proper corrections for temperature; and it was not until Dr. O. Hecker, using the method suggested by Mohn of Christiania, made elaborate experimental measurements,* under the auspices of the International Geodetic Bureau, on board the steamer Petropolis, of the Hamburg-South American Line, between Europe and Brazil, in the summer of 1901, that the first actual measures of the intensity of gravity over an oceanic basin were determined.

---

* "Bestimmung der Schwerkraft auf dem Atlantischen Ozean sowie in Rio de Janeiro, Lissabon, und Madrid," von O. Hecker, Königl. Preussischen Geodatischen Institutes, neue folge, No. 11, Verlag von P. Stankiewicz, Berlin, 1903.

The operation consisted of employing, side by side, a boiling-point apparatus and a mercurial barometer, and comparing the true pressure of the atmosphere as indicated by the temperature of unconfined steam with the pressure indicated by the height of the barometric column.

In the mercurial barometer a mass of mercury is made to mount to a certain height in balancing the pressure of the atmosphere; and this height is greater or less, for the same absolute pressure of the atmosphere, according to the weight of the mass of mercury in the barometric column. And since the weight of a given mass of matter is dependent upon gravity, a definite relation must exist, at any given place, between the height of the mercurial barometer and the boiling-point of water. This relation is altered on going to another place where the intensity of gravity is different, and hence the comparison of the readings of the mercurial barometer and the boiling-point thermometer affords the means of determining the variation of the intensity of gravity from place to place.

The practical applicability of the method depends upon the exactness with which the instrumental readings can be observed on board a ship at sea. With a good barometer, the barometric reading can be obtained to within an amount ranging from one-fiftieth to one-twentieth of a millimeter. To obtain with the hysometer an exactness corresponding to that with which the barometer can be read, the thermometer should give the boiling-point temperature to within such a fraction of a degree as corresponds to a few hundredths of a millimeter on the mercury column. At a barometric height of 760 millimeters, one-tenth of a millimeter corresponds to 0.0037 of a degree of temperature, or one one-hundredth of a millimeter to 0.00037 of a degree; and at a barometric height of 650 millimeters, one-tenth of a millimeter corresponds to 0.005 of a degree of temperature and one one-hundredth of a millimeter to 0.0005 of a degree. Hence to obtain the true atmospheric pressure to within one-twentieth of a millimeter, the boiling-point thermometer should give the temperature to within 0.002 of a degree.

In spite of the refinements demanded and of the necessity for eliminating the effects of the movements of the observing platform upon the barometric column, memorable results* have been attained in voyages traversing the Pacific and Indian oceans as well as the Atlantic, which exercise a broad influence in geography.

---

* "Bestimmung der Schwerkraft auf dem Indischen und Grossen Ozean und an deren Küsten," von O. Hecker, Zentralbureau der Internationalen Erdmessung, neue folge No. 16, Georg Reimer, Berlin, 1908.

Before this achievement, knowledge in relation to the intensity of gravity and its variations on the globe was confined to the land masses; and geodesists, taking together the available measurements of the intensity of the gravity resulting from pendulum experiments in various parts of the world and the observed deflections of the vertical disclosed by the comparison of geodetic triangulation with astronomical observations, had deduced a theoretical expression for the normal value of gravity at sea level according to which its intensity was represented as increasing from the equator to the poles by increments proportional to the square of the sine of the latitude and the square of the sine of twice the latitude jointly. Standard gravity was defined as the intensity of gravity in latitude 45° at sea level, and meteorologists had adopted the custom of reducing barometer readings made both on the land and on the ocean to standard gravity as computed from this theoretical expression. It was therefore a matter of import to meteorology that it should be ascertained, by observation and measurement, whether the theoretical variation of the intensity of gravity with latitude actually applied to the oceanic as well as to the continental areas. The general results of the relative determinations that have been made at sea is to establish the fact that gravity is normal over the surface of the ocean. Locally, as in the vicinity of the Tonga Islands, there are irregularities; and there is a highly interesting variation in intensity in passing outward from a continent to the deep sea, according to which the intensity is in excess in the shallow coastal waters, in defect at the beginning of the deep sea, and thence of normal value.

Moreover, studies of pendulum and geodetic observations had also given rise, during the last century, to theories respecting the distribution of matter inside of the earth, and these could not be confirmed or extended until the intensity of gravity over the oceanic areas was made known. Exact triangulation and surveying had revealed a relation between the deflections of the plumb line and the plateaus, mountains, and valleys constituting the visible irregularities of the earth's surface; but computations had shown that the deflections of the vertical which must be produced by the attraction of these visible irregularities of the earth's surface are much greater than those which are observed, and that beneath the crust of the earth there must be such a distribution of the densities of materials as will bring about an incomplete balancing of the effects of the visible topography upon the direction of the plumb line. The recognition of this relation between the sub-surface densities and the surface irregularities of the earth was the foundation of the doctrine of isostacy, which postulates that above a certain depth, at which the pressures in the interior of the earth are equal in all directions as in a perfect fluid, there will be in every vertical-sided, inverted, truncated pyramid, of equal cross section, reaching to the surface of the earth, the same amount of matter. Thus, if it be true, as geodesists have computed,* that the depth of compensation is 114 kilometers below the sea level, any column extending down to this depth below sea level, and having one square kilometer for its base, has the same mass as any other such column. One such column, located under a mountainous region, may be 3 kilometers longer than another located under the sea coast. On the other hand, the solid portion of such a column under one of the deep parts of the ocean may be 5 kilometers shorter than the column at the coast. Yet, according to the doctrine of isostacy, each of these three columns will contain the same quantity of matter. The masses being equal and the lengths of the columns different, it follows that the mean density of the column beneath the mountainous region is 3 parts in 114 less than the mean density of the column under the sea coast. So, also, if the intensity of gravity is normal over the surface of the ocean, the mean density of the solid portion of the sub-oceanic column would have to be in excess of the mean density of the seacoast column by an amount somewhat less than 5 parts in 114, seeing that the water of the ocean virtually constitutes a part of the column.

Inasmuch as actual measurements have shown that the intensity of gravity is normal over the Atlantic, Pacific, and Indian oceans, the theory of isostacy is validated, for not only must the superficial masses of continents be compensated by a defect of density in the earth's crust beneath them, but the lightness of the ocean must also be compensated by an excess of density under the ocean bed.

To be able to say that, through a thickness of 70 miles, the mean density of the earth's crust is 7 per cent. greater under the floor of the ocean than under the continents is to limit the range of controversial subjects connected with terrestrial physics.

Concerning the dispute as to whether the oceans have always had the same general extent and positions since the waters were gathered together or as to whether, by alternate rising and sinking of the earth's crust, oceans and continents have successively occupied the same areas, the deciding stroke appears to have been delivered in favor of the permanence of ocean basins, on account of the extreme improbability that there could be such a shifting of materials in the depths of the earth's crust as would cause the sub-oceanic heaviness to give place to the sub-continental lightness which has been found to subsist.

---

* "The Figure of the Earth and Isostacy from Measurements in the United States," by John F. Hayford, Inspector of Geodetic Work, and Chief, Computing Division, Coast and Geodetic Survey. Department of Commerce and Labor, Coast and Geodetic Survey, Washington, Government Printing Office, 1909.

Henceforth, more definiteness of thought may, therefore, characterize the treatment of the train of geographical questions which depend upon the delimitation and the circulation of the oceans, and their effect upon evolutionary processes.

A NEW MAP OF ARABIA

A map of Arabia on a scale of 32 miles to an inch is at present under publication in India. The compilation, from all available sources of information, is by Captain F. Fraser Hunter, Indian Army, of the Survey of India, and is the result of some years of diligent research.

The projection is the same as that adopted by the Survey of India for the 32-mile-to-the-inch map of India—*i. e.,* the modified secant-conical, a feature of which is that there is no central meridian. This projection enables the map of Arabia to be fitted alongside the map of India, thus giving, at a glance, a map of that portion of the world between Burma and Egypt. It should be possible, later, to produce other such maps to include China and Africa.

Captain Hunter's map of Arabia is the first and only one compiled on so large a scale, and it should shed much light on hitherto obscure points in the geography of that region and be a stimulus to more exact inquiry in the future.

The main points of interest in this new map are: Charles Huber's notes have been recompiled and all his astronomical observations worked out and corrected. His barometric readings have been reduced to their correct value by comparison with sea-level readings, taken, at the same instants, at the Survey of India tidal stations at Bombay, Bushehr and Aden (Loomis's Formula).